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A NEW CRINOID FROM THE PUTNAM HILL LIMESTONE MEMBER (ALLEGHENY GROUP, PENNSYLVANIAN) OF OHIO

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ABSTRACT

An inadunate crinoid, *Diphuicrinus ohioensis* sp. nov., from the Putnam Hill Limestone, Allegheny Group, Middle Pennsylvanian of Ohio is described. Features of the dorsal cup that characterize the species are (1) width more than three times the height, (2) similarity to cups of *D. patina* Strimple and Knapp and *D. coalensis* Strimple and Moore in lateral profile, (3) pentagonal outline in ventral view, (4) radial forefacets less deep than internal facetal areas, (5) prominence of anal X, and (6) small nodes on infrabasals and proximal portions of basals; large discrete nodes on remainder of cup.

The genus *Diphuicrinus* Moore and Plummer, 1938, is considered to compose an aberrant line of Pennsylvanian crinoids and to be the sole representative of the family Diphuicrinidae. The genus *Graffhamicrinus* Strimple, 1961, is regarded as invalid, because based on surface ornament, an inadequate criterion for generic distinction; the genus is here treated as a junior subjective synonym of *Delocrinus* Miller and Gurley, 1890. Study of the holotype of *Delocrinus aristatus* Strimple shows it to be a typical representative of *Diphuicrinus*; the species is here designated *Diphuicrinus aristatus* (Strimple, 1949) comb. nov.

INTRODUCTION

Specimens comprising the types of a new species of the Pennsylvanian crinoid genus *Diphuicrinus* described in the following pages are repositied in the Cleveland Museum of Natural History (CMNH), the National Museum of Natural History (USNM) and Orton Museum, Ohio State University (OSU). The Orton Museum specimens were formerly in the collection of the Geology Depart-

ment of Ohio University. Dr. Myron Sturgeon of that institution kindly permitted me to describe them.

I am indebted to Dr. Patrick Sutherland of the University of Oklahoma (OU), to Mr. Harrel Strimple of the University of Iowa (SUI), and to Mr. James Murphy of Case Western Reserve University for the opportunity to study crinoid material pertinent to this investigation. I thank Dr. Mildred Walmsley for technical assistance in preparation of this paper.

REGISTER OF LOCALITIES

All of the crinoid specimens designated as types of the new species described herein were collected from shaly portions of the Putnam Hill Limestone Member, Allegheny Group, Pennsylvanian, in Elk Township, Vinton County, Ohio, near the town of McArthur. Morningstar (1922) applied the name McArthur Limestone to the unit from which these crinoids were taken, but the name Putnam Hill Limestone (Andrews, 1870) has priority over Morningstar's appellation and is the term currently used in Ohio. Locations of the collecting sites are given in the following summary:

Locality 1: Abandoned strip mine east of township road 17, in the SE $\frac{1}{4}$ sec. 7, Elk Twp., Vinton County, Ohio (lat $39^{\circ}16'45''$ N., long $82^{\circ}30'31''$ W.) 4.4 km northwest of McArthur, Ohio.

Locality 2: Abandoned strip mine NE of township road 17, in the NE $\frac{1}{4}$ sec. 17, Elk Twp., Vinton County, Ohio (lat $39^{\circ}16'26''$ N., long $82^{\circ}30'10''$ W.) 3.5 km northwest of McArthur, Ohio.

Locality 3: Abandoned strip mine in the NE $\frac{1}{4}$ sec. 17, Elk Twp., Vinton County, Ohio (lat $39^{\circ}16'35''$ N., long $82^{\circ}29'40''$ W.) north and east of a tributary of Elk Fork, and 3.4 km northwest of McArthur, Ohio. The original label notes that the locality is "across the ravine from the old Moore mine." The Moore mine was designated the type locality of the McArthur Limestone by Morningstar (1922).

SYSTEMATIC PALEONTOLOGY

Class CRINOIDEA Miller, 1821

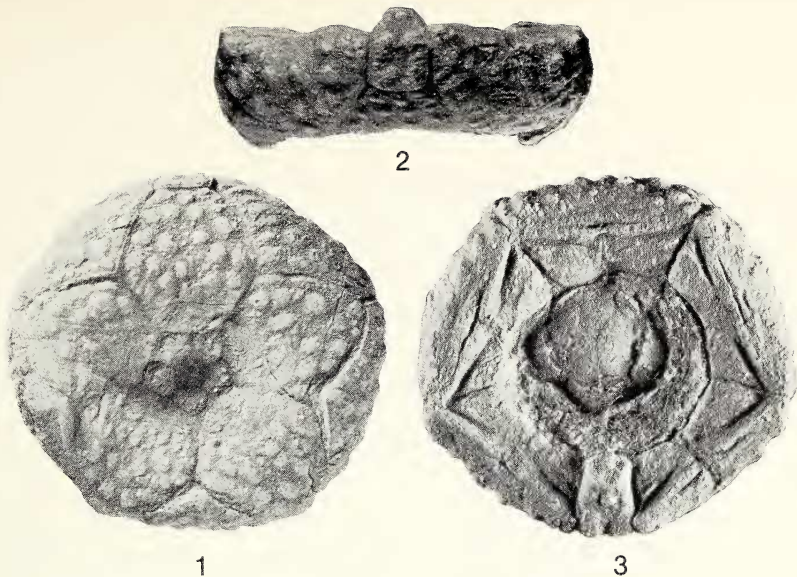
Family DIPHUICRINIDAE Strimple and Knapp, 1966

Genus DIPHUICRINUS Moore and Plummer, 1938

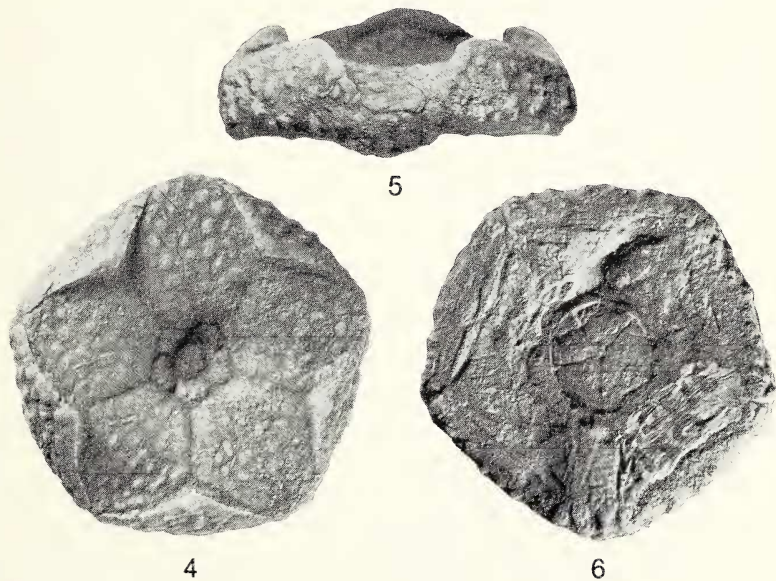
Diphuicrinus ohioensis sp. nov.

Figs. 1-9

Diagnosis: Dorsal cup more than three times wider than high (H/W ratio about 0.30) and near that of *D. coalensis* Strimple and Moore in size; resembles cups of *D. coalensis* Strimple and Moore and *D. patina* Strimple and Knapp in lateral profile; outline somewhat rounded in dorsal view, pentagonal in ven-



Figures 1-3. *Diphuicrinus ohioensis*, sp. nov. Holotype, CMNH 3800, from the Putnam Hill Limestone, Allegheny Group, Vinton County, Ohio. Fig. 1, dorsal view; fig. 2; posterior view; fig. 3, ventral view. All x2.



Figures 4-6. *Diphuicrinus ohioensis*, sp. nov. Paratype, OSU 31504, from the Putnam Hill Limestone, Allegheny Group, Vinton County, Ohio. Fig. 4, dorsal view; fig. 5, posterior view (dorsal side up). Note collapsed basals, and radials still in place. Fig. 6, ventral view. All x2.

tral view; radial forefacet less deep than internal facetal area; anal X a prominent component of cup. Principal ornament large discrete nodes on anal X, radials and distal portions of basals; smaller nodes on infrabasals and proximal region of basals.

Types: Holotype CMNH 3800, collected by Delbert Windle. Paratypes: OSU 31504, collected by Myron Sturgeon and Richard Hoare; OSU 31503, collected by Don Crissinger; USNM 166575 and USNM 166576 (partial dorsal cup), both collected by James Murphy.

Occurrence: Putnam Hill Limestone Member, Allegheny Group, Pennsylvanian.

Localities: Elk Township, Vinton County, Ohio (see Register of Localities). Holotype, CMNH 3800 and paratype OSU 31503 from Locality 1. Paratype OSU 31504 from Locality 2. Paratypes USNM 166575 and USNM 166576 from Locality 3.

Description: Dorsal cup low truncate bowl-shaped, more than three times wider than high, rounded pentagonal in dorsal outline, pentagonal in ventral. Lateral walls steep. Height and width dimensions of basal impression more than half those of the cup. Slopes of impression moderate. Infrabasals convex, discrete, gently downflaring, of medium size.

Basals with moderate but steepest slopes within basal impression; nearly flat proximally, maximum longitudinal curvature in vicinity of basal plane, less along lateral wall; slightly concave transversely in region of basal plane. Interbasal sutures inconspicuous. Distal borders of basals slightly curved. Except for CD basal, little exposure of basals on lateral wall. CD basal quite elongate, truncate distally.

Proximal tips of radials mark basal plane. Radial slopes gentle proximally, conforming with those of basals, but steep along lateral wall. Transverse convexity of radials slight. Forefacet less deep than internal facetal area. Outer facetal ridge sturdy in holotype. External ligament pit slitlike, transverse ridge elevated, remarkably slender and sharp, denticulate. Inner facetal area faces inward. Lateral furrows narrow. Adsutural slopes steep, adsutural valley floors rising with lateral ridges. Lateral lobes with winglike borders. Intermuscular notch very broad. Intermuscular furrow short, extends to intermuscular elevation separating rounded muscular-basin areas.

Anal X slightly damaged in holotype, partly recumbent and moderately elevated on internal side, with about one-third of height above summits of radials; shows two distal facets; proximally rests on truncated tip of CD basal. In all the types anal X is prominent component of cup.

Ornament of basals, radials and anal X consists mainly of fairly large, well-separated nodes, with a few small nodes scattered among them. Small nodes

predominant on proximal parts of basals. Small nodes also present on infra-basals.

Measurements: Linear measurements, in mm, taken on two specimens are as follows: CMNH 3800 (holotype) - Dorsal cup height, 7.1 (appr.), width, 24.0 (appr.), H/W ratio, 0.30, basal impression height, 4.0, width, 13.0; infrabasal circlet, width, 5.7; basal (EA) length, 8.4, width, 8.7; radial (A) length, 6.7 width, 12.8; suture between basals, length, 4.7 (appr.), suture between radials, length, 4.0; anal X, height, 5.9, width 3.9. OSU 31504 (paratype) - Dorsal cup height, 7.1, width 22.2, H/W ratio, 0.32; basal impression width, 13.8; radial (E) length, 6.6, width, 12.6.

Comparisons: Dorsal cups of *Diphuicrinus ohioensis* sp. nov., *D. patina* Strimple and Knapp, and *D. coalensis* Strimple and Moore agree in showing, in lateral profile, subparallel, almost plane, dorsal and ventral borders, steep lateral walls (least steep in *D. coalensis*) and width of cup more than three times the height. In dorsal and ventral views, *D. patina* is more rounded; in ventral view, *D. ohioensis* and *D. coalensis* are definitely pentagonal. In *D. patina* the radial forefacet is as deep as the internal ligament area; in *D. coalensis* and *D. ohioensis* it is less. In *D. ohioensis* the large nodes are more prominent; they are also more discrete than in *D. patina*, less sparse than in *D. coalensis*. The infra-basals are nodose in *D. ohioensis*, not ornamented in *D. patina*, and evidently not ornamented in *D. coalensis* also. Anal X is a prominent plate in *D. ohioensis*, of moderate size in *D. patina*, and reduced in *D. coalensis*. The holotype of *D. ohioensis* greatly exceeds that of *D. patina* in size, but is nearly the same size as the holotype of *D. coalensis*. The figured paratype of *D. patina*, SUI 11901 (Strimple and Knapp, 1966, fig. 23) which is larger than the holotype of *D. patina*, quite clearly does not belong to that species, and possibly does not pertain to *Diphuicrinus*. It shows peculiar depressions along the interbasal sutures that are not characteristic of *Diphuicrinus*, but the dorsal cup is too poorly preserved for definite allocation.

Discussion: Moore and Plummer (1937, p. 311) indicated that they based the genus *Diphuicrinus* on "the structure of the calyx, including the deep ligament fossae of the suture faces . . .". The deep ligament fossae are a characteristic feature of *Diphuicrinus*, it is true, as shown both by isolated plates and by plates still in association within the cup. However, the fossae do not persist throughout the life span of the animal. Some isolated radial and basal plates display them on all suture faces. These plates must pertain to young animals, for other plates show the fossae filled with calcareous upgrowths that make flush contacts with similar deposits on suture faces of adjoining plates. Along such contacts the plates tend to be bound together; apparently at this stage they were connected, not only by ligaments, but also by calcareous deposits. This last stage is first

traceable along the interradiial sutures (and along the sutures between the posterior radials and anal X). It is not unusual to find specimens of *Diphuicrinus* in which the basals, although still lying within the dorsal cup, have fallen away from sutural contact with the radials and infrabasals. My paratypes of *Diphuicrinus ohioensis* demonstrate this (see Figures 4-5). The radials of these dorsal cups continue to remain upright, bound together interradially in normal position in the cup. At later growth stages, however, the other fossae of the radials and those of the basals became filled with calcareous deposits also, and if the cup is preserved the plates are usually found in place, as they were in the living animal. This seems to hold for the three dorsal cups included in the type suite of *Diphuicrinus croneisi* Moore and Plummer, the type species of the genus, and may be taken as indicating a degree of maturity for these specimens.

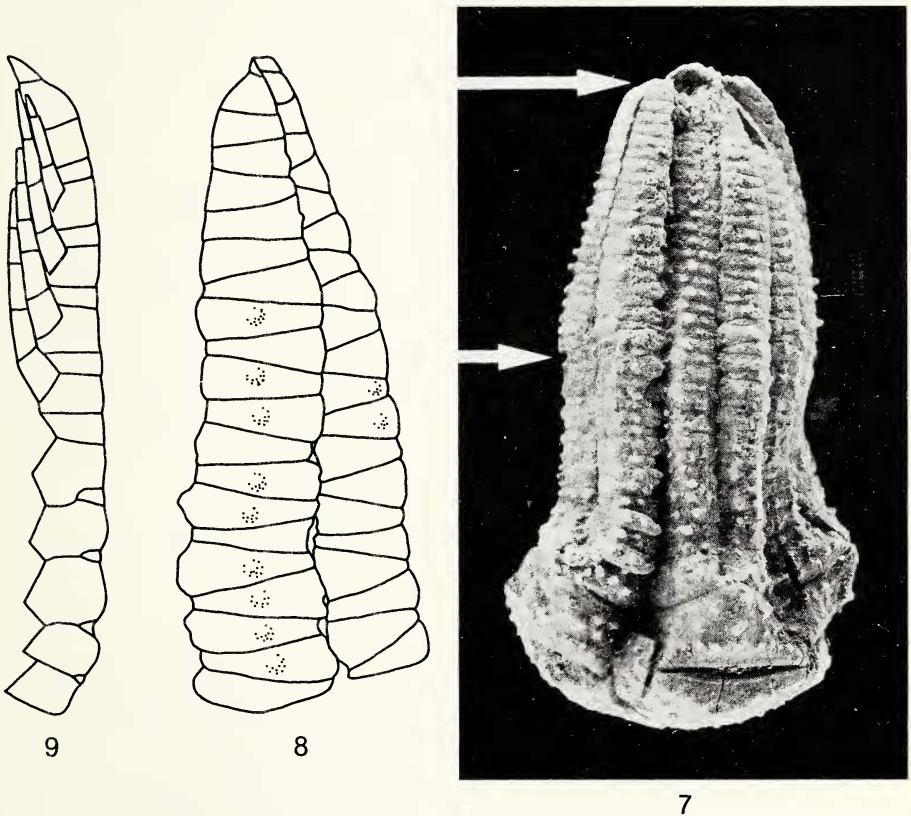
Now it is of great interest that this final stage in sutural contact seems nearly to have been attained by the cup plates of the holotype of *Diphuicrinus faustus* Moore and Strimple, OU 7511. Portions of the articular surfaces of the D radial and the DE basal of this specimen are exposed because the E radial has slipped inward. Both the interradiial and the radial-basal suture faces show surfaces that are practically flush, with elevations occupying the places of the fossae and crenellae showing along the ridges.

The arms of *Diphuicrinus* are known from two specimens, both attributed to *Diphuicrinus faustus* Moore and Strimple by those authors (1973). The arms of the holotype, OU 7511, were illustrated by Moore and Strimple (1973, pl. 14, fig. 1a; pl. 15, fig. 4a). The crown of the paratype of *D. faustus*, OU 4597, was figured by Strimple and Knapp (1966, pl. 36, figs. 1, 2) but the specimen, as depicted more recently by Moore and Strimple (1973, pl. 14, figs. 1b, 1d) no longer retains all of the surface detail of the arms, probably because of rash use of an air abrasive machine in preparation.

Study of these two specimens gives support to my previous suggestion (Burke, 1970, p. 9-10) that mature individuals of *Diphuicrinus* would be found to have biserial arm structure. In the midregions of the arms of these two crowns of *Diphuicrinus faustus*, biseriality appears to be already under way. The secundibrachs are quite cuneate; some of them are reduced to feather edges on the antipinnular side and do not extend the full width of the arm. But this is not fully apparent in external view, because the pinnular ends of some of the brachs are intruded between the pinnular ends of brachs of adjoining arms, which makes for a remarkably robust interlocking mechanism, but the interlocking brachs conceal the underlying structure of the arm. It is only the external portions of the brachs which mesh with and slightly overlap the brachs of adjoining arms. This is evident when the arms are separated. Actually, at depth, subjacent and superjacent pinnular ends of some of the secundibrachs are in

contact, and where they are in contact they fence off the tips of the antipinnular wedges, preventing them from extending the full width of the arm.

I have attempted to illustrate the arm structure of the holotype of *Diphuicrinus faustus*, OU 7511, in Figures 7, 8, and 9. In Figure 7, a right posterior view of the crown, the interlocking secundibrachs are shown. Notches are evident in the right side of the arm of the D ray, which is elevated above and does not mesh with the adjoining arm. The region between the arrows on the left side of the figure includes the portions of the arms of the D ray which are illustrated in Figures 8 and 9.



Figures 7-9. *Diphuicrinus faustus* Moore and Strimble. Holotype, OU 7511. Fig. 7, right posterior view of crown, x2. Arrows delimit portions of D ray illustrated in figs. 8 and 9. Fig. 8, external view of portions of both arms of D ray, x 4.6. Fig. 9, lateral view of portion of left arm of D ray, x 4.6.

The proximal secundibrachs of these arms of the D ray of OU 7511 are not satisfactorily preserved, consequently in Figures 8 and 9 only that part of the left arm beginning with the 15th secundibrach, and of the right arm the portion originating with the 17th secundibrach, are illustrated. Neither arm is quite complete distally. In Figure 8, an external view, both arms display the notches between secundibrachs, which become increasingly prominent proximad; distad the notches are less distinct and are not evident on the terminal parts of the arms. The left arm interlocks with the right, but it is free on the left side, because the right arm of the E ray is displaced and lies a greater depth. On this free side of the left arm it is evident that the antipinnular ends of the secundibrachs are exposed laterally, but there is no indication of the extent of their exposure at depth. In Figure 9, the extent of their lateral exposure is evident.

Figure 9 is a lateral view of this same part of the left arm of the D ray. Distad, some of the pinnules are preserved. But proximad lies the region of greatest interest, for here are exposed the pinnular ends of five secundibrachs with subjacent and superjacent surfaces in contact at depth. External to the junctures of the pinnular ends of these secundibrachs, four antipinnular tips of secundibrachs are seen, cut off from lateral exposure at depth, and progressively decreasing in size and extent of lateral exposure proximad (an indication that the antipinnular sides of the secundibrachs were being resorbed). There seems no escaping the conclusion that this arm was becoming biserial, and in fact exhibits biseriality in this region, where five successive secundibrachs on one side are in contact and pinnulate. In advance of this region the antipinnular ends of secundibrachs intervene between pinnular ends in typical uniserial fashion, and a few notches are evident. It is apparent that the interlocking structures of these arms were developed before the attainment of biseriality.

Burdick and Strimple (1973) have demonstrated that arms of fully mature specimens of *Phanocrinus* attain a stage of incipient biseriality, with all the brachs on each side pinnulate, but the arms are not biserial in any strict sense of the word. The cuneate brachs of *Diphuicrinus* are far more advanced than those of *Phanocrinus*, but whether any species of *Diphuicrinus* ever acquired biserial arms comparable to those of *Delocrinus*—or to those of Morrowan contemporaries of *Diphuicrinus*, such as *Endelocrinus*, remains to be demonstrated.

Whatever its ultimate assignment, *Diphuicrinus* is quite evidently a valid and distinct genus. Apparently the taxon is composed of species remarkable for their slow attainment of maturity, as demonstrated by the dorsal cup, which in some specimens appears literally to be "falling apart at the seams," and also by the arms, which in the two crowns that are known show only the beginnings of biseriality, although Strimple and Moore (1971) regarded one of them (OU

4597) as "young but mature." Another feature of *Diphuicrinus*, the coarse ornament, suggested "specialization" to Strimple and Knapp (1966). Coarse ornament does not characterize all of the species, but when present it is so marked that it might better be regarded as evidence of overspecialization. In general, there is much about *Diphuicrinus* that seems to me to indicate a crinoid stock in decline; something akin to phylogerontism appears to be in evidence here. I am inclined to view the taxon as a sterile offshoot of the *Phanocrinus* stock, which gave rise to no other Pennsylvanian genera, and which probably became extinct in Desmoinesian time. I consider it to be the sole member of the family Diphuicrinidae, as did Strimple and Knapp (1966). In view of the various unique characteristics of *Diphuicrinus*, the family deserves full recognition. However, it was originally assumed that *Diphuicrinus* was distinguished by uniserial arm structure, and this was the sole basis for establishment of the family. It is now evident that uniseriality simply represents a stage in the ontogeny of the diphuicrinid arm and does not constitute grounds for family distinction.

Almost any attempt to clarify the relationship of *Diphuicrinus* to several other genera contemporary with it would involve detailed taxonomic discussion beyond the scope of this paper. Nevertheless, one instance of generic confusion relates directly to *Diphuicrinus* and needs citation here. It stems from Strimple's (1961) proposal of the genus *Graffhamicrinus*, with *Graffhamicrinus acutus* as the type species. This crinoid is an ornate form, bearing a few superficial nodes on the cup plates and brachials; otherwise there is little to distinguish it from smooth-plated species of *Delocrinus*. Strimple founded his genus, and distinguished it from *Delocrinus*, on the basis of surface ornament of various types. Inasmuch as surface ornament alone, such as typifies *Graffhamicrinus acutus*, is not regarded by most crinoid authorities as sufficient grounds for generic distinction, I have refused to recognize *Graffhamicrinus* as a valid genus (Burke, 1966, 1970), relegating it to synonymy under *Delocrinus*, and continue to advocate its suppression.

However, within the omnium-gatherum of species which Strimple included under *Graffhamicrinus* there are some which in addition to surface ornament, show diagnostic features which entitle them to recognition as representatives of distinct genera. One of these was originally described as *Delocrinus aristatus* by Strimple (1949). Probably this species, more than any other, has been regarded as the connecting link between *Diphuicrinus* on the one hand and *Delocrinus* (= *Graffhamicrinus*) on the other. Of this taxon Pabian and Strimple (1974, p. 15) state: "*Graffhamicrinus aristatus* appears to be a very primitive representative of this genus. The radial facets, contour of the cup, and attitude of the anal plate strongly suggest a relationship to *Diphuicrinus* Moore and Plummer." I have recently examined the holotype of this species, an incom-

plete dorsal cup, USNM S 4690, and find it a typical example of *Diphuicrinus*; it shows a steep-walled basal impression, tips of radials in the basal plane, and a distinct forefacet. In lateral profile it resembles OU 6446, the specimen figured by Strimple and Moore (1971, figs. 9-11) and identified as *Diphuicrinus coalensis*? Strimple and Moore. It also resembles OU 6445, the holotype of *Diphuicrinus coalensis*, in showing a much reduced stem. I am herewith designating the species *Diphuicrinus aristatus* (Strimple, 1949) comb. nov. If this species, or any other species of *Diphuicrinus*, is assumed to be either closely related or ancestral to *Delocrinus* (= *Graffhamicrinus*) I fail to find evidence to support that assumption.

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